
**Submarine Base, Groton, Conn.**

REPORT NUMBER 697

# THE INTELLIGIBILITY OF PROCESSED HELIUM SPEECH AT DIVING DEPTHS GREATER THAN 1000 FEET

by

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Bureau of Medicine and Surgery, Navy Department
Research Work Unit M4306.03-2020DAC5.05

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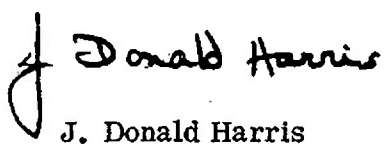

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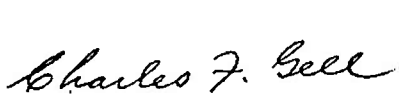

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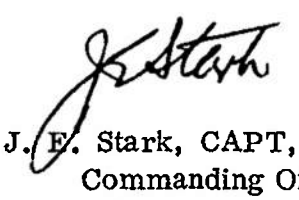

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## SUMMARY PAGE

### THE PROBLEM

To evaluate speech processed through a helium speech unscrambler at depths below 1000 feet during a working dive.

### FINDINGS

Speech was found to be highly intelligible over the limited set of conditions used in this study. The findings warrant additional rigorous testing under more varied conditions.

### APPLICATION

If such a device is found to be applicable under the many conditions which the Navy diver/swimmer usually operates, communication between diver and tender and between two divers would allow additional freedom in the world of underwater exploration.

## ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit M4303-03-2020DAC5.05 - Evaluation of Underwater Communications Systems for Navy Divers. The present report is No. 5 on this work unit. It was approved for publication on 17 Jan 1972, and designated as Naval Submarine Medical Research Laboratory Report No. 697.

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## ABSTRACT

The purpose of this study was to evaluate the intelligibility of a helium speech unscrambler undergoing development by the Admiralty Research Laboratory, Teddington, England. Tapes of divers reading sentence lists at three depths in a helium-rich environment were played to five panels of listeners, each containing 15 members. Fifty words within each sentence list were chosen for evaluation. The overall mean intelligibility score for two divers at 1050 and 1500 feet and one diver at 1250 feet was 92.2 percent. The average score at the deepest depth was slightly lower than the average score at 1050 feet. For the limited conditions evaluated, the unscrambler appeared to operate effectively. Additional evaluation under various conditions using standardized intelligibility test material is necessary to determine the overall applicability and effectiveness of this device.

# THE INTELLIGIBILITY OF PROCESSED HELIUM SPEECH AT DIVING DEPTHS GREATER THAN 1000 FEET

## INTRODUCTION

The majority of speech intelligibility testing under conditions of high ambient pressure has been confined to depths equivalent to approximately 800 feet of sea water or less. The results of these various studies which are summarized elsewhere [1,2] indicate that speech degradation increases markedly as depth increases. While other factors contribute to the drop in intelligibility, a change to greater pressure, when other factors are kept constant, will usually produce a corresponding drop in intelligibility. As yet, little is known about speech at depths beyond 800 feet. Moreover, when one talks of speech intelligibility at such great depths, one refers generally to speech processed through any of the class of devices known as helium speech unscramblers. The intelligibility scores of processed speech appear to be a function of the unscrambling device as well as depth[3]. While other factors, such as gas mixtures, talkers, word lists, and listening conditions contribute to the final intelligibility score, these can be minimized with the appropriate experimental controls. The unscrambler itself, however, has continued to be a focal point in the Navy's attempt to provide an adequate communications package to swimmers and divers. It is with this thought in mind that the present report was generated. In this report, results of intelligibility tests using a recently developed helium-speech unscrambler for communication to depths of 1500 feet are presented. It is hoped that these results provide a preliminary indication of the applicability of the unscrambler for use by Navy personnel and facilities.

## PROCEDURE

This report is based on tape recorded samples of speech produced during a working dive to a depth equivalent to 1500 feet of sea water in a helium-rich atmosphere. In the preparatory stages of the dive, it was not intended to study speech intelligibility; thus, the samples used in this study are not generally the type of material used to evaluate speech communication systems. However, it is felt that this evaluation may serve to indicate levels of speech intelligibility which are possible, using conversational-type material. The evaluation, therefore, cannot be validly compared with previous analyses of speech produced under pressure using standard intelligibility tests. It is only intended to provide preliminary quantitative information about a specific communication system. The system used was the Processor for Helium Speech developed by the Admirality Research Laboratory, Teddington, England*.

**Basically, this is a time-domain processing system which temporarily stores sections of the talker's speech and then reads them back at a lower rate. During the voiced portions, these sections are taken from the most intensive part of the laryngeal period and the remainder is rejected. During the unvoiced portions, the scanning is less regular but spaced closer in time. Thus, for such a pitch-synchronous device, the frequency compression resulting from the lower replay rate is inversely proportional to the time expansion.*[4]

From the recordings available, the intelligibility of two talkers at 1050 and 1500 feet and one talker at 1250 feet was obtained. Each talker read one of three sentence lists. For this study, only the first 10 sentences of each list were evaluated since they were approximately similar in content and length. The speech was originally recorded on an AMI 52 Magnetic Tape recorder and transferred to an Ampex 601 Tape recorder. The recordings processed through the unscrambler were presented to listening groups each containing 15 listeners who had passed an audiometric screening at 15 dB ISO. Each listening group heard a training list from one talker and a test list from a second talker. The training list was spoken by talker #2 at 1050 feet. In one case, however, the training list was that read by talker #1 at 1050 feet and the test list was that read by talker #2 at the same depth. The training and test lists were never the same list of sentences. Table 1 summarizes the listening conditions for this study.

All recordings were presented to the subjects binaurally through 15 matched sets of TDH-39 earphones which were fed by an Ampex 601 Tape Recorder at a comfortable loudness level. All subjects were Navy enlisted personnel. Ample time was given between each sentence for the subject to write the entire sentence on a form provided.

From each sentence list, fifty words were selected for evaluation by the investigator. These words might be broadly considered to be the content words in the sentences; prepositions, conjunctions and articles for the most part were excluded. Appendix I contains the three sentence lists with the test words underlined. It is suggested that the reader use caution in evaluating the results since it is commonly known that sentence material tends to inflate intelligibility scores due to the redundancy of such material. It was felt that this procedure, however, would not interfere with the validity of the tests since the primary concern was the

Table 1. The training lists, and test lists used for each group and depth evaluated:

| Group | TRAINING SESSION | | | TEST SESSION | | |
|---|---|---|---|---|---|---|
| | Depth Feet | Diver No. | List | Depth Feet | Diver No. | List |
| 1 | 1050 | 2 | A | 1050 | 1 | B |
| 2 | 1050 | 1 | B | 1050 | 2 | A |
| 3 | 1050 | 2 | A | 1250 | 1 | C |
| 4 | 1050 | 2 | A | 1500 | 1 | C |
| 5 | 1050 | 2 | A | 1500 | 2 | C |

relative differences at each depth. Moreover, since the sentence lists resembled each other in both content and length, the selection of words to evaluate was not completely arbitrary. Rather, the words were chosen only after comparing the content of all three lists.

## RESULTS

It should be pointed out that this study evaluated an unscrambler used during a working dive and that no attempt was made to evaluate the unprocessed speech. One group of subjects, however, heard the unprocessed speech at 1250 feet and 14 of the 15 listeners scored 10 percent or less.

The results of this study are shown in Table 2. For each talker/depth condition, the group means and standard deviations of the correct responses were computed. Table 2 indicates that over all five listening groups, a mean of 92.2 percent intelligibility was obtained. As to the scores for each depth and talker, Table 2 indicates that for Talker 1, the scores drop somewhat for each increment in depth. For Talker 2, there was essentially no difference in the mean scores obtained at 1050 and 1500 feet. From the groups tested, it can be concluded that highly intelligible speech transmission is possible at high ambient pressures.

Table 2. Percent correct and standard deviations for each of the listening groups.

| Group | Depth | Diver | Word List | Percent Correct | Standard Deviation |
|---|---|---|---|---|---|
| 1 | 1050 | 1 | B | 96.3 | 2.2 |
| 2 | 1050 | 2 | A | 94.8 | 3.6 |
| 3 | 1250 | 1 | C | 90.7 | 4.7 |
| 4 | 1500 | 1 | C | 84.1 | 7.9 |
| 5 | 1500 | 2 | C | 95.2 | 6.6 |
| Overall | | | | 92.2 | 4.4 |

No formal analysis of the phonemic errors was made due to the overall high intelligibility scores; however, several types of errors were consistently observed. First, the plosive sounds (p, b, t, d, k, g) were often incorrectly identified as fricatives such as (f, v, th, s). Also there appeared to be a consistent trend to substituting incorrect voiced phonemes for correct voiced phonemes; the same was true for the non-voiced sounds. These type of errors are consistent with those previously reported by Murray[5] for speech in a helium-rich environment.

## DISCUSSION

The results presented in this report indicate that speech can be transmitted from a helium gas mixture under high ambient pressures to the surface and maintain a high level of intelligibility when suitably processed through a helium unscrambler. The present study has demonstrated this for a limited set of conditions; however, it should be remembered that this cannot be considered a complete test of the helium unscrambling system for several reasons. First, the material used was not a standardized intelligibility test. Second, only two talkers were used. Finally, only specific words within a group of sentences were evaluated, a procedure which might tend to inflate the test scores due to the redundancy which exists in language. With these cautionary statements in mind, nonetheless, the present evaluation suggests that the possibility exists for divers, under certain conditions, to communicate effectively from a helium-rich environment at depths to 1500 feet.

It is suggested that further evaluation of the helium unscrambler developed by the British Admiralty be considered. These evaluations should include tests of a large number of talkers at various depths, gas mixtures, and with various degrees of background noise. Furthermore, standard intelligibility test material should be used in order to compare this system with one previously tested. Without such a comprehensive test, the applicability of any system cannot be attained.

In summary, this report concerns itself with a specific helium speech unscrambler. Sentence lists processed through the unscrambler were presented to subjects who wrote out the sentences. Fifty words from each list were evaluated in terms of their intelligibility. The results indicate that under the limited conditions of testing involved, speech was highly intelligible at 1050, 1250, and 1500 feet. A comprehensive evaluation of the system is recommended to determine its applicability for Navy diving operations.

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APPENDIX I. Sentences used in the present study to evaluate speech intelligibility. The underlined words were chosen as the test words for scoring purposes.

List A

1. Please write your surname.
2. How many toes do you have on each foot?
3. What time do you have breakfast?
4. Where do you live?
5. Write down the name of your doctor.
6. How many inches are there in a foot?
7. Please draw a square.
8. Name the highest mountain in the world.
9. How much does it cost to post a letter?
10. Who delivers your milk?

List B

1. Please state your initials.
2. How much sugar do you have in your tea?
3. What time do you leave work?
4. What is your first name?
5. Write down the number of your house.

List B (Continued)

6. How many pints are there in a gallon?
7. Please get an umbrella.
8. Name a large city in Scotland.
9. What does one keep in an acquarium?
10. Who is the American president?

List C

1. Is it noisy or quiet in there?
2. Do you drink tea with sugar or without sugar?
3. When did you start working here?
4. What must you do to lose weight?
5. Do write down the size of your shoes.
6. How do you get to work?
7. If you are to open a tin, what would you use?
8. Is this loud, soft or normal?
9. Write down the time.
10. What is the number of this question?